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PHYTOPLANKTON STANDING CROP AND SPECIES DIVERSTIY IN RELATION TO SOME WATER CHARACTERISTICS OF SUEZ BAY (RED SEA), EGYPT.

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Key words: *phytoplankton, nutrients, Suez Bay.*

ABSTRACT

Phytoplankton standing crop and species composition in Suez Bay were studied and discussed in relation to the environmental physico-chemical parameters during 2002-2003. A total of 80 species and varieties were recorded and identified at the selected stations of the bay. Of them 47 species and 29 genera of diatoms; 19 species and 11 genera of dinoflagellates; seven species of cyanophytes within four genera; six species of chlorophytes among four genera and one species of chrysophytes. Two main phytoplankton peaks were recorded during spring and autumn seasons (average of 15,676 and 15,376 unit.L^{-1} respectively). The diatom species responsible of these peaks were, *Nitzschia pungens* var. *atlantica, Asterionella japonica, Skeletonema costatum, Chaetoceros decipiens* and *Gyrosigma attenuatum.* The species diversity showed a minimum value at the sewage treating company (ABB station) ranging from 2.17-3.36 nats. While, the highest diversity values were recorded at the unpolluted station, Aiyoon Mousa (VI) and varied from 2.74-3.61 nats. The results revealed regional and seasonal inverse correlation between diversity and phytoplankton standing crop in Suez Bay and it is regarded as a pollution habitat.

The results of N:P ratio indicated that Suez Bay is generally P-limited, mainly due to the high load of nitrogenous compounds specially ammonia, which formed about 60.71 % of the total inorganic nitrogen, followed by nitrate (33.7 %) and nitrite (5.57 %). Dissolved inorganic phosphate recorded with annual average of 0.98 $\mu mol.L^{-1}$. Generally, the level of nutrient salts indicated that Suez Bay is in the eutrophic state.

INTRODUCTION

The Suez Bay (Fig.1) is a shallow extension of Suez Gulf at its northern part. The average length along its major axis is about 13.2 Km. Its average width along the minor axis is about 8.8 Km. The bay is connected to Suez Gulf through the south-eastern side and connected to Suez Canal by dredged channel of about 16 m depth through the north-eastern side. The bay is subjected to different sources of pollution. The first and dangerous one is the oil effluents that discharge from industrial complex south of Suez, which includes the oil refineries, El-Nasr and Suez Petroleum Companies. The second pollution source is the sewage of Suez City, which discharges into the bay. This sewage is recently treated by a treating company namely, ABB from 1994 till now.

The aim of this work is to evaluate the phytoplankton standing crop and diversity of the bay as a result of treating the sewage effluents of Suez City by ABB company. In addition to study the most physico-chemical parameters helping to define the bay water quality as a nutritive medium for phytoplankton production.

MATERIALS AND METHODS

Water and phytoplankton samples were collected seasonally through spring, summer and autumn of 2002 and winter, 2003. Six stations were chosen covering different ecological habitats of Suez Bay, namely, Port-Tawfik (I), EL-Zaitia (II), AL-Kabanon (III), ABB company (IV), Adabyia (V) and Aiyoon Mousa (VI) as presented in Fig.1. The former five stations are situated in the northwestern side of the bay, which is subjected to oil effluents and sewage of the Suez City. While station VI is located in the eastern direction of the bay, which is relatively far from the pollution sources and it could be considered as a control for the other sampling stations.

Water temperature was measured by using a simple pocket thermometer graduated to 0.1°C. The pH value of water samples was measured in situ using a pocket pH meter model Orion 210. The salinity of water was measured in the laboratory by using inductive salinometer (S.C.T. meter). Dissolved oxygen determination was carried out according to Winkler's method as described in APHA (1995). The biological oxygen demand (BOD) and chemical oxygen demand (COD) were determined according to the method reported in APHA (1989). Nutrient salts (NO_3, NO_2, NH_4, PO_4 and SiO_4) were determined spectrophotometrically according to the methods described by Strickland and Parsons (1968). Results of nutrients are expressed as $\mu mol.L^{-1}$.

Phytoplankton standing crop was determined by sedimentation method (Utermohl, 1936) and its magnitude is expressed in units per liter. For identification of the algal taxa, the following references were consulted; Peragallo and Peragallo (1908), Ghazzawi (1939), Cupp (1943), Bourrelly (1968) and Bold and Wynne (1978) for diatoms and silicoflagellates. Ferguson Wood (1968) for dinoflagellates. El-Nayal (1935), Huber-Pestaluzzi (1938) and Prescott (1962) for blue-green algae and Stewart and Mattox (1975) for green algae.

Diversity index was estimated on the computer according to the equation of Shannon & Weaver (1963) and expressed as nats. The correlation coefficient (r) was calculated between the total phytoplankton standing crop and some environmental parameters on the calculator.

RESULTS AND DISCUSSION

I. Physico-chemical conditions

1) Temperature

A limited variation in surface water temperature of the Suez Bay was observed and mainly depend on the sampling time. In general, the seasonal temperature variations follow those of the prevailing climate conditions. During this investigation, the mean water temperature ranged between a minimum of 17.33 °C during winter (2003) and a maximum of 28.33 °C during summer (2002). The dinoflagellates and blue-green algae showed their maximum flourishing during spring, which was associated with relatively high temperature (21-22.5 °C). These results are in accordance with that obtained by Ibrahim (1988) in Foul Bay of the Red Sea. *Ceratium fusus* of dinoflagellates was dominant in summer (August) at surface water temperature of 28-29 °C. In relation to eutrophication, temperature seems to have pronounced effect on the rate of phytoplankton photosynthesis as well as periodicity and abundance of phytoplankton species (Behrendt, 1990; Kobbia *et al.*, 1990 and Abdallah *et al.*, 1995a).

2) pH value

The pH value of water is controlled by the dissolved oxygen, water temperature, sewage discharge, decomposition of organic matter and photosynthetic activities. It lies in the alkaline side and varied within a narrow range (8.31-8.59) with annual average of 8.45 (Table 1). The pH values are relatively high as compared with that previously recorded in the same area (8.1-8.37) by Nassar (1994) and in Suez Gulf (7.78-8.38) by Nassar (2000). However, the relatively higher pH values were recorded during the warm seasons in which the rise in temperature usually stimulates phytoplankton photosynthetic activity causing more consumption of carbon dioxide and the rise of pH (Abdallah *et al.*, 1995a).

3) Water salinity

As shown in Table 1, the maximum value of salinity (41.85 ‰) was recorded at station VI during summer. The minimum value of 40.9 ‰ was occurred at station IV during winter, as a result of dilution by effluents discharged from sewage treating company ABB. The results indicated that the salinity of the surface water reached its maximum during summer and early autumn and the minimum in winter. This may be attributed to evaporation of water by the elevation of temperature, as well as the entrance of high salinity water from Suez Canal into the bay (Morcos, 1970). However, evaporation is one of the controlling factors for salinity and consequently density, circulation and sea level variation (Maiyza, 1988).

4) Dissolved Oxygen (DO)

Dissolved oxygen is the best parameter to show the effect of pollution in the aquatic ecosystem unless it contains toxic constituents (Lester, 1975). The data indicated that DO varied between a maximum of 6.66, 6.51 mg $O_2.L^{-1}$ at the stations I and II, respectively during autumn and minimum values of 4.2, 4.1 mg $O_2.L^{-1}$ at the stations V and VI, respectively during winter (Table 1). The slight increase of dissolved oxygen during autumn and spring was associated with highest flourishing of phytoplankton in these seasons (average of 15,376 and 15,676 unit.L^{-1}, respectively). This high oxygen content indicates a good mixing in the water column (Girgis, 1980). However, the results indicated a strong positive correlation between phytoplankton counts and dissolved oxygen ($r= 0.94$). Such result agrees with that obtained by Abdallah *et al.* (1995b); Gharib (1998) and Nassar (2000), who stated that dense phytoplankton correlated with high oxygen concentration.

5) Biological Oxygen Demand (BOD)

The biological oxygen demand is defined as the amount of oxygen consumed by the respiration process in a limited volume of water and incubated in the dark at constant temperature (20°C) for five days (APHA, 1989). The results showed that BOD varied between 4.61 mg $O_2.L^{-1}$ at St. IV during winter and 0.95 mg $O_2.L^{-1}$ during spring at St. VI, which is relatively far from the pollution sources. The high BOD values at St. IV may be due to direct effect of acute pollution by disposal of sewage wastes from Suez City. The low BOD level of St. VI proves its purity and this agrees with ANON (1975), who reported that a BOD of 1 ppm is a characteristic of nearly pure water.

6) Chemical oxygen demand (COD)

Another way to assess the degree of sewage pollution in Suez Bay is to measure the organic matter present in water samples taken periodically under the same sampling conditions. The results in Table 1 indicate that maximum COD value of 2.78 mg $O_2.L^{-1}$ occurred at St. IV during winter. Such value may be due to the effect of sewage effluents of Suez City. The minimum COD value of 0.56 mg $O_2.L^{-1}$ was recorded during spring at St. VI, which is virtually clean. The data revealed that BOD and COD values in Suez Bay showed a gradual increase southward, reaching their maximum value at St. IV, that lies in the vicinity of Suez City and receives its wastes.

7) Nutrients

a) Ammonia

Ammonia is biologically active compound present in most water as normal biological degradation product of organic nitrogen. It can be utilized directly as nutrients by several algal species and aquatic plants (UNESCO, 1988; Mahmoud, 1995 and Stolte and Riegman, 1995). The results in Table 1 showed that ammonia formed about 60.71 % of the total inorganic nitrogen in Suez Bay with an annual average of 9.15 $\mu mol.L^{-1}$. Ammonia contents were high at the relatively polluted stations IV and V specially in winter and summer seasons, during which lowest phytoplankton standing crop was recorded. In waters directly polluted by sewage or substantially polluted by river discharge, the concentrations of ammonia are often higher than 20 $\mu mol.L^{-1}$ as reported by UNESCO (1988). On the other hand, relatively low values of ammonia were observed during the most productive seasons, autumn and spring (Table 3). Consequently, the results revealed a strong inverse correlation ($r= -0.96$) between ammonia concentrations and phytoplankton standing crop. This finding agrees with the data reported by Abdallah *et al.* (1995b). However, it is clear that ammonia concentration was somewhat high at the northwestern coast of the bay and decreased at the eastern coast. This is almost due to the disposal of sewage and industrial effluents at the western and northwestern parts of the bay.

b) Nitrite

Regarding nitrite, the consideration of its concentrations in seawater is useful because of its intermediate oxidation state between ammonia and nitrate. But it has the highest toxicological significance of human health, if present in perceptible concentration in diets. Maximum nitrite concentration of 1.61 µmol.L^{-1} was recorded at St. V during winter (Table 1). Such value is in quite agreement with the presence of ammonia at the same station and during the same season. The minimum value of nitrite being 0.26 µmol.L^{-1} occurred at St. VI during autumn. In general, nitrite is not a stable end product, its absence or presence in such quantities might not be so peculiar. Sverdrup *et al.* (1949) reported a range of nitrite from 0.01 to 3.5 µmol.L^{-1} in the sea. However, in the investigated area and during the low temperature season (winter), nitrite concentration showed the maximum value (average of 1.07 µmol.L^{-1}). This may be attributed to nitrate reduction at low oxygen levels.

c) Nitrate

Nitrate is considered as the most stable and predominant inorganic nitrogen form in seawater. The results showed that nitrate content formed about 33.7 % of the total inorganic nitrogen in Suez Bay. The maximum nitrate concentrations were 10.73 and 11.54 µmol.L^{-1} occurred at the stations IV and V, respectively during autumn, in which the high flourishing of phytoplankton was observed. The minimum nitrate value of 2.0 µmol.L^{-1} was recorded at St. VI during winter, when the lowest counts of phytoplankton. Generally, the increase in nitrate content of seawater is followed by an increase in both production and chlorophyll-a level (Saad and Fahmy, 1984). Hamed (1992) reported that surface nitrate concentration in Suez Bay varied between 18.0 and 0.43 µmol.L^{-1}. However, the results indicated a significant positive correlation ($r= 0.97$) between dissolved nitrate and phytoplankton standing crop, which coincided with the data reported by Nassar (2000).

d) Phosphate

As presented in Table 1, the dissolved inorganic phosphate in Suez Bay fluctuated between a maximum of 1.78, 1.52 µmol.L^{-1} at the relatively polluted stations IV and V, respectively during winter and a minimum of 0.27 µmol.L^{-1} at the unpolluted station VI during autumn. Hamed (1992) indicated that the average of phosphate concentration in the surface water of Suez Bay was 0.85 µmol.L^{-1}.

The dissolved phosphate values of 0.47 and 0.81 μmol.L^{-1} were recorded in the Gulf of Suez and Suez Canal, respectively (Hamed, 1996). Stirn (1972) reported that the normal seawater contains dissolved phosphate in the range of 0.0-0.3 μmol.L^{-1}, which is relatively coincided with the results of the present study at St. VI. Whereas, in the oceans, phosphate fluctuates between 0.2 and 3.5 μmol.L^{-1}. In comparison with the Gulf of Aden and Red Sea, concentration of dissolved inorganic phosphate in the Suez Gulf is relatively low (Morcos, 1970). However, a significant inverse correlation coefficient ($r= - 0.74$) was observed between dissolved phosphate and phytoplankton standing crop.

e) Nitrogen-phosphorus ratio (N:P)

The N:P ratio appeared to be an important ecological parameter because it gives account for dominance and succession of algal species and eutrophication (Smith, 1983). Riley and Skirrow (1967) showed that a relatively constant N:P ratio of 15:1 was found statistically on a world scale. Generally, the N:P ratio varies from one location to the other depending on the seasonal variability of quality and quantity of wastes discharged into the study area. In this connection, Chiaudani and Vighi (1978) reported that marine algae, in general, are P-limited at N:P ratio > 6 and N-limited at the ratio of < 4.5, while in the range of 4.5-6, the two nutrients are near their optimal assimilative proportion. In the present study, the water of Suez Bay was generally P-limited, mainly due to the high load of nitrogenous compounds specially ammonia, that reached its highest values at the relatively polluted stations IV and V. The annual average of N:P ratio was 15.49. In conclusion, the level of nutrient salts indicated that Suez Bay is in the eutrophic state according to the standard levels reported by Franco (1983).

f) Silicate

Regarding silicate content, the highest values of 4.4 and 4.66 μmol.L^{-1} were found at the stations V and VI, respectively during winter, at which the diatoms showed their lowest numbers. On the other hand, the lowest silicate values of 1.21 and 1.3 μmol.L^{-1} were recorded at the stations I and II, respectively, during spring, which sustained the highest flourishing of diatoms as indicated in Table 3. However, the pronounced decrease in silicate content during autumn and spring may be due to the flourishing diatoms at that time. In accordance with the results of this study; Harding (1992), Gharib and Soliman (1998) and Nassar (2000) reported the depletion of silica was always associated with flourishing of diatom populations. Moreover, an inverse correlation between silicate and diatom population ($r=-0.88$) was recorded and this agrees with the findings reported by by Kobbia (1982); Harding (1992); Abdallah *et al.* (1995a); Gharib and Soliman (1998) and Nassar (2000).

II. Phytoplankton standing crop

-Community composition and distribution

Total of 80 species comprising 47 Bacillariophyceae, 19 Dinophyceae, 7 Cyanobacteria, 6 Chlorophyceae and one rarely form of Chrysophyceae (Table 4). Bacillariophyceae was the most dominant group forming about 76.68 % by number to the total phytoplankton standing crop. Dinophyceae was recorded with moderate counts constituting about 20.94 % of the total phytoplankton. Cyanobacteria and Chlorophyceae were observed with small counts forming about 1.92 and 0.35 % of the total phytoplankton, respectively. On the other hand, Chrysophyceae was represented by only one species (Table 2).

The highest standing crop of phytoplankton was found at the stations, Port-Tawfik (I), EL-Zaitia (II) and AL-Kabanon (III) with average counts of 13,440, 13,763 and 12,389 unit.L^{-1}, respectively. This may be attributed to the low fractions of petroleum hydrocarbons discharged from the oil refineries, El-Nasr and Suez petroleum companies. These oil fractions could be stimulating the standing crop of phytoplankton as previously recorded by Rinkevich and Loya (1983) and Nassar (1994). On the other hand, the relative low counts were found at the unpolluted station, Aiyoon Mousa (VI) with an average value of 7,007 unit.L^{-1}, although the highest diversity of species was observed at this station. However, some species are responsible for flourishing of phytoplankton at stations I, II and III namely, *Nitzschia pungens* var. *atlantica*, *Asterionella japonica*, *Skeletonema costatum*, *Chaetoceros decipiens*, *Gyrosigma attenuatum* and *Chaetoceros curvisetus* of diatoms, as well as *Ceratium furca*, *C. trichoceros* and *C. fusus* of dinoflagellates.

- Seasonal distribution

Spring followed by autumn (2002) were the most productive seasons when phytoplankton crop reached to 15,676 and 15,376 unit.L^{-1}, respectively (Table 3). This is due to the high population density of the diatoms, *Nitzschia pungens* var. *atlantica* and *Chaetoceros decipiens* during autumn, as well as the flourishing of *Asterionella japonica*, *Skeletonema costatum* and *Gyrosigma attenuatum* during spring season (Table 5). These results are supported by those of Levanon-Spainer *et al.* (1979), Khalil *et al.* (1984), Khalil and Ibrahim (1987 and 1988) and Nassar (2000). They reported that the Red Sea exhibited a different and unique trend in which autumn represented the most productive season.

Judging from the previous study of Suez Bay (Nassar, 1994); about 71% of the recorded species in the present study were previously detected, whereas about 12 species of diatoms (*Chaetoceros lorenzianus, C. peruvianus, C. coarctatus, Hemiaulus heibergii, Biddulphia mobiliensis, B. obtusa, Climacodium biconcavum, Coscinodiscus granii, Licmophora gracilis, Gramatophora marina, Thalassiothrix longissima* and *Fragillaria* sp.); five species of dinoflagellates (*Ceratium minutum, Peridinium divergens, Pyrophacus horologicum, Goniaulax minuta* and *Oxytoxum scolopax*); two species of Cyanobacteria (*Oscillatoria tenuis* and *Spirulina platensis*) and four species of green algae (*Scenedesmus bijuga, S. dimorphus, Staurastrum paradoxum* and *Stigoclonium* sp.) could be considered as new records in Suez Bay in the present study. The fresh and brackish water species were observed in front of the sewage treating station (ABB), due to large quantities of fresh inland water discharged from the sewage treating company of Suez City. Generally, some of these records were previously reported in Suez Canal, Suez Gulf and Red Sea by Halim (1969), Dowidar (1976), Dowidar *et al.* (1978), Ibrahim (1988), El-Sherif and Ibrahim (1993), El-Sherif and Abo El-Ezz (2000) and Nassar (2000).

In conclusion, comparison of the present study with that recorded by Nassar (1994), the results indicated that the standing crop of phytoplankton showed sever drop and decreased from 106,861 unit.L^{-1} (previous study) to 10,810 unit.L^{-1} (present study), while the total number of species is slightly increased from 76 species in the previous study to 80 species in the present study (Table 4). On the other hand, slight increase in the number of species of both blue-green and green algae was observed, which attributed to the freshwater discharged from the sewage treating company (ABB) of Suez City.

- Species diversity

Results of diversity in Suez Bay sustained good variations of species as indicated by the averages of 3.36, 2.58, 3.13 and 2.4 nats during winter, spring, summer and autumn, respectively. The highest diversity value of 3.61 nats was recorded at the unpolluted station, Aiyoon Mousa (VI) during winter. This could be attributed to the increased number of species (40 species), which reflects the absence of distinct dominance of any particular species, where the dominance at St. VI during winter was shared by several species. On the other hand, the lowest diversity appeared at the sewage treating station, ABB (IV) during autumn with 2.17 nats, where the more frequent diatom, *Nitzschia pungens* var. *atlantica* formed about 53 % of the total phytoplankton at this station during autumn. However, the species diversity of phytoplankton declines markedly during the period of great change in the environmental factors and also may be due to the nutritional levels and their availability (Abdallah *et al.*, 1992; El-Sherif, 1993; Zaghloul, 1994 and 1995; El-Sherif and Zaghloul, 1994; Gharib, 1998 and Nassar, 2000).

Furthermore, results revealed regional and seasonal inverse correlation between diversity and the standing crop of phytoplankton in the Suez Bay (r= - 0.58 and - 0.97, respectively) and it is regarded as a polluted habitat.

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Table 1: Water characteristics of Suez Bay during 2002-2003

Season	Spring (2002)						Summer (2002)					
Station	I	II	III	IV	V	VI	I	II	III	IV	V	VI
Temp.	21.0	21.0	21.0	22.0	22.5	22.5	28.0	28.0	28.0	28.0	29.0	29.0
PH	8.41	8.42	8.44	8.47	8.45	8.38	8.48	8.49	8.53	8.59	8.55	8.47
Salinity	41.2	41.3	41.1	41.0	41.11	41.7	41.7	41.7	41.3	41.2	41.7	41.85
DO	6.35	6.4	6.11	5.5	5.0	4.37	5.43	5.2	4.8	5.1	4.91	4.75
BOD	2.26	2.31	2.64	3.27	3.08	0.95	2.54	2.86	3.21	4.0	3.26	1.58
COD	0.88	1.1	1.43	2.31	1.92	0.56	1.2	1.36	1.68	2.56	2.08	0.88
PO_4	0.73	0.86	0.97	1.34	1.1	0.47	0.9	0.96	1.10	1.25	1.00	0.50
NO_3	8.76	8.91	6.98	4.91	3.76	2.93	6.20	5.83	3.96	3.28	4.51	2.66
NO_2	0.31	0.4	0.66	0.92	1.2	0.19	0.84	0.9	1.08	1.17	1.27	0.45
NH_4	5.08	4.94	7.23	10.6	11.8	2.0	5.93	6.29	8.43	18.0	19.76	2.81
SiO_4	1.21	1.3	2.15	2.25	2.68	3.21	2.49	2.10	2.86	3.00	3.88	4.08

Table 1: Continued

Season	Autumn (2002)						Winter (2003)					
Station	I	II	III	IV	V	VI	I	II	III	IV	V	VI
Temp.	23.5	23.5	24.0	24.0	24.0	24.0	17.0	17.0	17.0	17.5	17.5	18.0
pH	8.46	8.47	8.5	8.53	8.52	8.4	8.35	8.39	8.40	8.49	8.41	8.31
Salinity	41.5	41.6	41.3	41.1	41.5	41.75	41.0	41.1	41.0	40.9	41.1	41.45
DO	6.66	6.51	6.3	5.4	5.55	5.79	5.4	5.15	5.30	4.90	4.20	4.10
BOD	2.86	2.54	2.98	3.4	3.16	1.22	2.78	2.91	3.11	4.61	3.76	1.71
COD	1.47	1.25	1.61	2.16	1.74	0.68	1.33	1.40	1.20	2.78	2.33	1.05
PO_4	0.61	0.86	1.22	1.41	0.87	0.27	1.0	1.11	1.17	1.78	1.52	0.61
NO_3	3.25	4.22	4.98	10.73	11.54	3.0	5.0	4.8	3.3	3.0	3.68	2.0
NO_2	0.41	0.54	0.78	1.1	1.3	0.26	0.86	0.99	0.82	1.5	1.61	0.67
NH_4	7.07	8.52	5.52	13.3	11.09	2.14	6.15	7.0	9.11	20.86	22.43	3.60
SiO_4	1.45	1.54	2.08	2.33	2.6	3.87	3.00	2.25	3.21	3.66	4.40	4.66

Note: Temp. = temperature (°C); DO = dissolved oxygen ($mgO_2.L^{-1}$)*; BOD = biological oxygen demand* ($mgO_2.L^{-1}$)*; COD = chemical oxygen demand* ($mgO_2.L^{-1}$) *and the nutrients,* PO_4, NO_3, NO_2, NH_4 *&* SiO_4 ($\mu mol.L^{-1}$).

Table 2: Annual average counts of different phytoplankton classes ($unit.L^{-1}$) in Suez Bay during 2002-2003.

Station Class	I	II	III	IV	V	VI	%
Bacillariophyceae	10,528	10.675	9.490	7.467	6.427	5,144	76.68
Chrysophyceae	17	17	0.0	17	0.0	17	0.1
Dinophyceae	2,656	2,913	2.714	1.612	2,048	1.640	20.94
Cyanobacteria	239	158	149	310	186	206	1.92
Chlorophyceae	0.0	0.0	36	193	0.0	0.0	0.35
Total	13.440	13.763	12.389	9,599	8,661	7.007	100

Table 3: Seasonal variations of different phytoplankton classes ($unit.L^{-1}$) in Suez Bay (average of the six stations) during 2002-2003

Season Class	Spring	Summer	Autumn	Winter	Average
	2002			2003	
Bacillariophyceae	11,952	2,938	14,034	4,231	8,289
Chrysophyceae	0.0	44	0.0	0.0	11
Dinophyceae	3,344	3,185	1,261	1,265	2,264
Cyanobacteria	287	204	70	271	208
Chlorophyceae	93	48	11	0.0	38
Total	15,676	6,419	15,376	5,767	10,810

Table 4: Comparison between phytoplankton production in Suez Bay before and after treating the sewage of Suez City by ABB Company

Class	Suez Bay, 1992 (Nassar, 1994)		Suez Bay, Present study	
	genus	Species	Genus	Species
Bacillariophyceae	32	49	29	47
Chrysophyceae	1	1	1	1
Dinophyceae	11	18	11	19
Cyanobacteria	5	5	4	7
Chlorophyceae	3	3	4	6
Total	52	76	49	80
Standing crop (unit.L^{-1})	106,861		10,810	

Table 5: List of the recorded species of phytoplankton in Suez Bay and their seasonal distribution (average of the six stations, unit.L^{-1}) during 2002-2003

Season	Spring	Summer	Autumn	Winter	Average
Class	2002			2003	
Bacillariophyceae					
Nitzschia pungens var. *atlantica* Cleve	370	85	5,600	303	1,590
N. longissima Ehr.	162	126	106	130	131
N. sigma Kutz	222	89	82	102	124
Asterionella japonica Cleve	4,797	134	579	150	1,415
Skeletonema costatum (Grev.) Cleve	2,475	39	316	267	774
Chaetoceros decipiens Cleve	0.0	75	1,925	480	620
C. curvisetus Cleve	102	78	1,675	124	495
C. tortissimus Gran.	0.0	52	176	0.0	57
C. lorenzianus Grun.	0.0	0.0	51	0.0	13
C peruvianus Brightwell	21	0.0	11	0.0	8
C. coarctatus Lauder	13	0.0	0.0	0.0	3
Gyrosigma attenuatum Ehr.	1,494	357	137	195	546
G. balticum Her.	35	0.0	0.0	0.0	9
Rhizosolenia alata f. *gracillima* (Cleve)	614	153	727	188	420
R. alata f. *indica* H. Peragallo	171	0.0	72	73	79
R. imbricata var. *shrubsolei* (Cleve)	119	0.0	137	69	81
R. calcar avis M. Schultze	0.0	79	87	71	59
R. stolterfothii H. Peragallo	121	0.0	115	0.0	59
Leptocylindrus danicus Cleve	149	77	274	977	369
Hemiaulus heibergii Cleve	47	91	724	123	246
Surirella ovata Kutz	101	339	124	118	170
S. robusta Ehr.	9	0.0	11	0.0	5
Biddulphia mobiliensis Bail.	61	205	183	138	147
B. obtusa Kutz	0.0	46	0.0	0.0	12
B. sp.	11	33	24	0.0	17

Table 5: Continued

Guinardia flaccida H. Peragallo	159	116	180	132	147
Campylodiscus noricus var. *hibernica* Ehr.	106	87	76	71	85
Amphora marina Smith	72	80	80	100	83
Amphiprora paludosa W. Smith	117	68	31	72	72
A. alata Kutz	0.0	0.0	45	0.0	11
Cerataulina bergonii H. Peragallo	0.0	46	160	69	69
Navicula gracilis Cleve	57	68	71	76	68
Melosira sulcata (Ehr.) Kutz	32	80	69	69	62
Climacodium biconcavum Cleve	132	24	21	67	61
Coscinodiscus radiatus Ehr.	0.0	154	11	0.0	41
C. granii Gough	24	0.0	47	0.0	18
C. centralis Her.	13	0.0	11	0.0	6
Lauderia borealis Gran	98	0.0	39	0.0	34
Licmophora gracilis (Ehr.) Grunow	0.0	22	0.0	67	22
Thalassionema nitzschioides Gran.	0.0	54	13	0.0	17
Diploneis interrupta (Kutz) Cleve	0.0	22	22	0.0	11
Synedra crystallina Lyngb.	37	0.0	0.0	0.0	9
Climacosphenia moniligera Ehr.	0.0	24	0.0	0.0	6
Gramatophora marina (Lyngb.) Kutz	0.0	24	0.0	0.0	6
Thalassiothrix longissima Cleve and Grun.	0.0	11	11	0.0	6
Fragillaria sp.	11	0.0	0.0	0.0	3
Striatella unipunctata Lyngb.	0.0	0.0	11	0.0	3
Dinophyceae					
Ceratium fusus Ehr.	129	1,616	78	88	478
C. trichoceros (Ehr.) Kofoid	1,261	179	84	118	411
C. furca Ehr.	985	161	85	159	347
C. massiliense (Gourret) Jorgensen	364	0.0	0.0	105	117
C. egyptiacum Halim	13	74	225	107	104
C. tripos (O. M. Muller) Nitzsch.	124	80	78	105	97
C. minutum Jorgensen	0.0	0.0	11	0.0	3
Peridinium cerasus Paulsen	101	120	144	127	123
P. depressum Bailey	91	110	111	97	102
P. divergens Ehr.	66	84	105	70	81

Table 5: Continued

Dinophysis caudata Savielle-Kent	111	199	108	71	122
Exuviaella marina Ostenfeld	77	118	91	80	91
Prorocentrum micans Ehr.	0.0	111	71	69	63
Diplopsalis rotunda (Lebour) Wood	0.0	82	37	69	47
Phalacroma rapa Stein	0.0	121	22	0.0	36
Pyrophacus horologicum Stein	0.0	108	11	0.0	30
Goniaulax minuta Kofoid and Michener	22	0.0	0.0	0.0	5
Oxytoxum scolopax Stein	0.0	11	0.0	0.0	3
Parahistoneis acuta Bohm	0.0	11	0.0	0.0	3
Cyanobacteria					
Oscillatoria erythraeum Drouet	172	35	0.0	200	102
O. tenuis Agardh	54	95	0.0	0.0	37
O. sp.	0.0	33	37	71	35
Spirulina platensis Nordst.	13	41	11	0.0	16
S. major KG.	24	0.0	11	0.0	9
Merismopedia punctata Smith	24	0.0	0.0	0.0	6
Lyngbya majuscula Harvey	0.0	0.0	11	0.0	3
Chlorophyceae					
Scenedesmus quadricauda Breb.	58	13	0.0	0.0	18
S. bijuga Turp.	35	0.0	0.0	0.0	8
S. dimorphus Turp.	0.0	11	0.0	0.0	3
Pediastrum clathratum Lemm.	0.0	13	0.0	0.0	3
Staurastrum paradoxum Menegh	0.0	11	0.0	0.0	3
Stigoclonium sp.	0.0	0.0	11	0.0	3
Chrysophyceae					
Dictyocha fibula Ehr.	0.0	44	0.0	0.0	11
Total standing crop (unit.L^{-1})	**15,676**	**6,419**	**15,376**	**5,767**	**10,810**

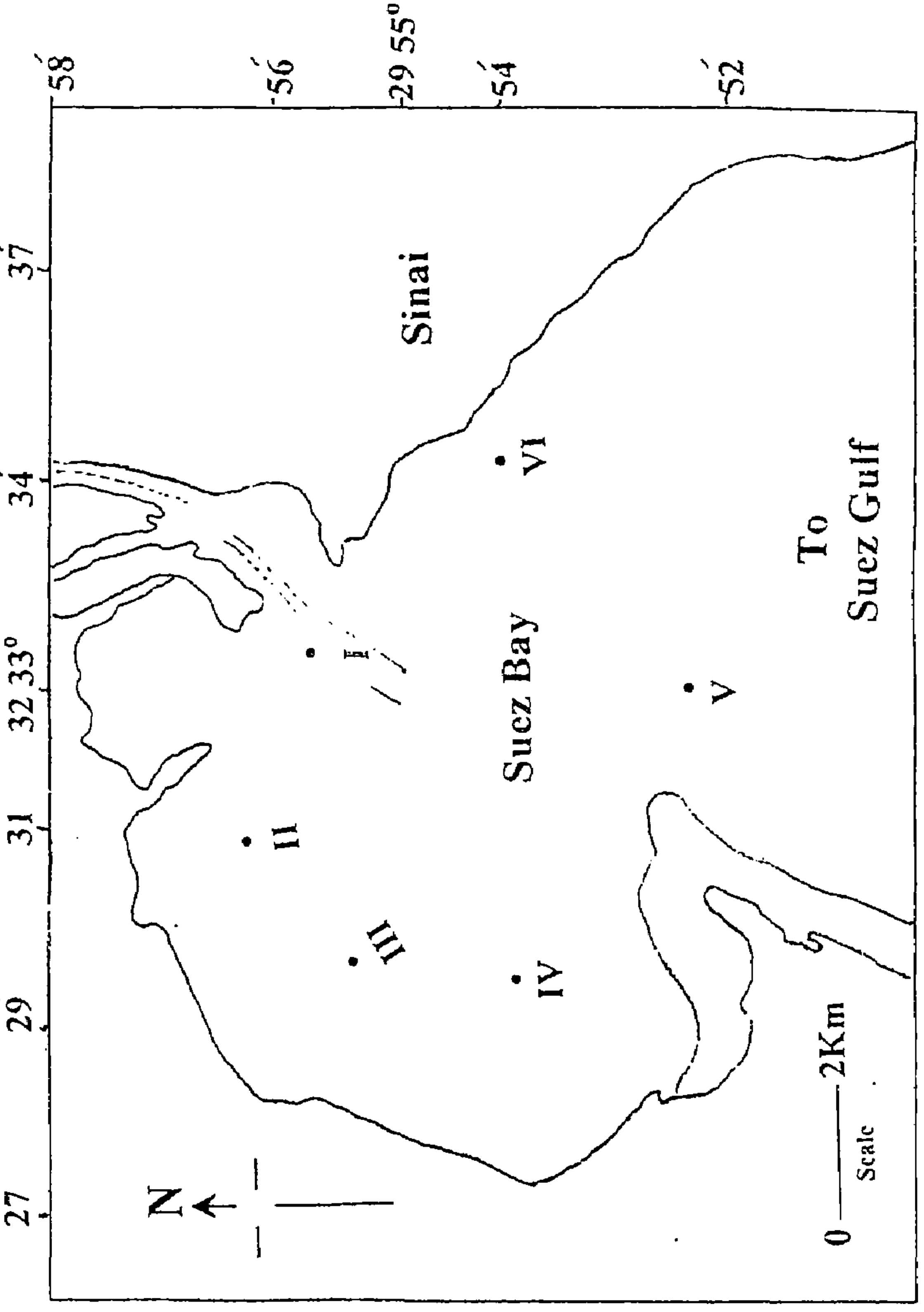

Fig. 1: Position of the sampling stations (I-VI).